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Engineering Note

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Project: Solenoid Energization, Controls, Interlocks and Quench Protection
Doc. No: H970423A

Subject: Design Review - Absolute Value Module

Introduction -- The purpose of this report is to provide an independent review of Walt Jaskierny's Absolute Value NIM Module. The source document for this report is drawing #3823-111-ED-330052, sheet 6 of 12. The primary purpose of this NIM module is to convert the bipolar analog output signal from the Holec current transductor into a unipolar analog signal. This signal is then routed to the 5000 amp Power Engineering Industries (PEI) power supply to provide current feedback for the regulation circuits. This module is needed because the PEI current regulator requires a unipolar feedback signal. The Holec current transductor is located downstream of the reversing switch and thus will be sensing current flowing in both directions depending on the polarity. The downstream location was chosen in order to measure only the solenoid currents and not the currents which are bypassed by the dump resistor. This module performs additional functions related to safety and monitoring.

Functions -- The module performs the following functions:

- Convert Holec current transductor output bi-polar signal into unipolar signal and provide buffered outputs of unipolar signal to power supply (for regulation), control system (for monitoring), and quench detector (for current compensation during charging).
- Monitor Holec current transductor output signal and PEI current transducer output signal for "output above adjustable threshold" conditions and provide relay contact (DC Overcurrent).
- Monitor Holec current transductor output signal and PEI current transducer output signal for "Holec low vs. PEI" condition and provide relay contact (Xducer valid).
- Monitor Holec transductor output signal, PEI current transducer output signal and PEI voltage output signal for "output below fixed threshold" condition and provide relay contact (<25A).

Features -- The module provides the following inputs and outputs:

Inputs:

- Mag Curr-1 -- Bipolar analog output voltage from Holec transductor. -10 to +10V = -5000 to +5000A solenoid bus current.
- PS Curr -- Unipolar analog output voltage from PEI current transducer. 0 to 10V = 0 to 5000A power supply current.
- PS Volts -- Unipolar analog output voltage from PEI buffer amp. 0 to 10V = 0 to 35V power supply voltage.
- Reset Intl -- External contact input. Closed contact resets latch of "Holec low vs. PEI, Holec Overcurrent, PEI Overcurrent".
- NIM Power Supply -- +24V, +15V, -15V

Outputs:

- Mag Curr-2 -- This is just a paralleled copy of Mag Curr-1. Unbuffered, it is intended to be monitored by the control system PLC.
- ABS I-1 -- Four wire, Differential output signal to power supply current regulator. 0 to 10V represents 0 to 5000A as sensed by the Holec transductor and converted to absolute value on this module.

- ABS I-2 -- Two wire, Differential output signal to the control system PLC for monitoring. 0 to 10V represents 0 to 5000A as sensed by the Holec transductor and converted to absolute value on this module.
- ABS I-3 -- Two wire, Differential output signal to the quench detector module for current compensation during charging. 0 to 10V represents 0 to 5000A as sensed by the Holec transductor and converted to absolute value on this module.
- Xducer Valid-1 -- Normally open relay contact. Held closed as long as this module determines that the transducer signals are valid. It does this by comparing the holec current transductor output with the PEI current transducer output. The contact opens if the Holec value is less than the PEI value (as compensated for dump resistor current and 25A for tolerances). This contact is used as an interlock by the interlock module.
- DC Overcurr-1 -- Normally open relay contact. Held closed as long as this module determines that both the Holec and PEI current signals are not indicating an overcurrent condition. This contact is used as an interlock by the interlock module.
- <25A-1 -- Normally open relay contact. Held closed as long as this module determines that both the Holec and PEI current transducers are indicating less than 25 Amps; and the PEI voltage output is less than 0.175 Volts. This contact is used to interlock the reversing switch.
- Xducer Valid-2 -- Identical to Xducer Valid-1. Not used by system.
- DC Overcurr-2 -- Identical to DC Overcurr-1. Not used by system.
- <25A-2 -- Identical to <25A-1. This contact is routed to the PLC control system for monitoring.

LED Indicators, Switches and Test Points:

- Holec Overcurrent -- Red LED -- latched. Indicates when lit that the Holec current transductor signal has exceeded a predetermined threshold. The threshold is adjustable by PC mounted potentiometer during calibration of the module. The limits are 25 to 5300 Amps. A test point is provided for setting the potentiometer. At the test point, 1 volt = 500 Amp threshold.
- Holec Low vs PEI -- Red LED -- latched. Indicates when lit that the Holec current transductor signal has deviated to less than it should be as compared to the PEI current transducer signal. Note that the PEI current transducer signal is modified by the PEI voltage signal as well as an offset signal. This is to compensate for the current flowing in the dump resistor upstream of the Holec transducer and to avoid nuisance trips.
- PEI Overcurrent -- Red LED -- latched. Indicates when lit that the PEI current transducer signal has exceeded a predetermined threshold. The threshold is the same one used for the Holec Overcurrent indicator described above.
- Holec Zero Current -- Green LED -- not latched. Indicates when lit that the Holec current transductor signal is less than 50 mV which corresponds to less than 25 Amps.
- PEI Zero Current -- Green LED -- not latched. Indicates when lit that the PEI current transducer signal is less than 50 mV which corresponds to less that 25 Amps.
- PEI Zero-Voltage -- Green LED -- not latched. Indicates when lit that the PEI output voltage is less than ± 0.175 volts.
- Absolute Value Test Points -- Front panel test points connected directly to the output of the absolute value circuit. Useful for examining the signal before it has been buffered for output to PLC, quench detector and power supply.
- Overcurrent Reference Test Point and Adjustment Pot -- For setting the point at which the Holec current or "net PEI" current trips the overcurrent threshold detectors. This is adjustable from 50mV to 10V which corresponds to 25A to 5000A.
- Reset Switch -- Front panel mounted SPST push button switch to reset the "Xducer Valid" and "DC Overcurrent" latches and relay contacts.

Circuit Descriptions

- Holec Current Absolute Value Circuit -- The output from the Holec transductor is a single ended signal ranging from -10 to +10 Volts which represents -5000 to +5000 Amps. The signal and return enters via shielded twisted pair through two NIM pins. The shield of the cable is grounded to the NIM chassis before entering the module and not at the Holec chassis. The signal return is connected to signal ground on the module. The signal and signal return are "daisy-chained" back out through NIM pins to be monitored directly by the control system. The signal is processed by a standard absolute value circuit constructed from two op amps and several diodes. This circuit has a gain of one and can process an input signal ranging from nearly -15V to +15V. The output will thus range from 0V to nearly +15V. The circuit employs driven guard rings and matched resistors to reduce drifting due to component aging and temperature. Offset adjustment pots are provided for each op amp.

- Output Buffer Amplifiers -- Once it is conditioned by the absolute value circuit, the signal, which is now of positive polarity, is routed to three buffer amplifiers. The first amp buffers the signal with a gain of one and delivers it and a signal return to NIM pins via 100 Ohm isolation resistors as a pseudo-differential signal with a Kelvin (4-wire) connection. This signal is meant to be routed to the 5000 Amp solenoid power supply for use by the current regulation circuits. The pseudo-differential connection is to provide some ground isolation between the devices. The Kelvin connection is to compensate for any voltage drop in the connection to the power supply. Driven guard rings and matched resistors are used here and in the next two buffer amps to reduce drifting due to component aging and temperature. The frequency response of the amp is shaped by a capacitor in the feedback network to be -3db at 1.59kHz and to roll off at 20 dB per decade.

  The next two buffer amps are identical to each other and differ only from the first by the lack of a Kelvin connection on the output. These amps are used to provide the PLC control system with the absolute current value for monitoring; and the quench detector circuits with the absolute current value for current compensation to allow for "tighter" quench detection windows. The PLC is within the same rack and the quench detector is within the same NIM bin. Thus, pseudo-differential connections are more than adequate and Kelvin connections are not required. The feedback connections, which are brought out as Kelvin connections on the first amp, are connected locally instead.

- Input PEI V&I Circuits -- These circuits receive the differential voltage and current signals from the PEI power supply. The signals arrive via shielded twisted pair with the shields grounded at the NIM chassis and not at the PEI power supply. The signals are fed into instrumentation amps via NIM pins and isolation resistors. The instrumentation amplifiers provide differential to single ended conversion with unity gain. Each signal is then fed directly to zero current threshold circuits and to the net PEI current circuit.

- Zero Current Threshold Circuits -- These circuits receive signals from the Holec current transductor absolute value circuit, and the Input PEI V&I Circuits. Comparators hold the "<25A" contact closed if: (absolute Holec current is less than 25A AND PEI current is less than 25A AND PEI voltage is less than 0.175V and PEI voltage is greater than -0.175V. Separate green LEDs are lit for each of the above current conditions; and a single green LED is lit if both voltage conditions are met.

- Net PEI Current Circuit -- The buffered input PEI V & I signals are also processed in an op amp adder circuit. The adder circuit provides a "net PEI current" signal to be compared elsewhere on the module with the Holec current signal to make sure both transducers agree. The "net PEI current is the total PEI current minus that current which ends up in the dump resistor. To do that, the adder circuit computes the dump resistor current by normalizing the power supply voltage signal and dividing it by the dump resistance. The calculated dump resistor current, and an additional 25 Amps for tolerance, is subtracted from the PEI current transducer signal and this new "net PEI current" signal is passed on to the current comparator circuits.

- Current Comparator Circuits -- These circuits monitor the signals from the Holec current transductor absolute value circuit and from the PEI current transducer "net PEI" current circuit. Several comparisons are made including Holec overcurrent (as compared to an adjustable overcurrent reference), Holec low vs. PEI, and "net PEI" current overcurrent (as compared to the same adjustable overcurrent reference). If any of the above comparisons are true, then latches are set to record each particular fault. The fault will remain latched until reset by an external contact closure in the control system. Front panel red LEDs indicate the fault. If the "Holec low vs PEI" fault occurs, then the "Xducer valid" contact, which has been held closed, will be released

to its open position. Also, if either overcurrent fault occurs, then the "DC Overcurrent" contact, which has been held closed, will be released to its open position.

- Reset Circuit -- This circuit provides for an input for an external contact closure from the control system to reset the current comparator latch circuits and thus the "Xducer valid" and "DC overcurrent" contacts. The input is received via shielded twisted pair with the shield grounded to the NIM chassis and not at the control system source. This circuit provides +24V with 2.2K in series to the signal line. The external contact merely makes a connection between signal and return to reset the module. The signal is isolated with another 2.2k resistor and optically couple into the module. The reset common is connected to signal ground. A monostable multivibrator extends the reset time. The multivibrator is triggered either by the remote closure or by a front panel mounted reset button.
- Power Supplies -- The module receives its power from the NIM crate power supply. +24V, +15V and -15V are supplied. Also, +1.2V is generated on the module from the +24V supply using two silicon rectifiers in series to ground with a 2.2k current limiting resistor.

Conclusion:

The module functionality and design are adequate for the stated purpose. Any design oversights which were discovered during the detailed examination of the circuits were corrected immediately through close interaction between the reviewer and the designer.